RULE-BASED SYSTEM FOR UPDATING SPATIAL DATA-BASE

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ABSTRACT:

Spatial Information revision and updating is the main concern and production effort of maintaining the ever-growing GIS systems and spatial data bases. Developing easily effected automatic updating methods of spatial information becomes the key to the successful maintenance of the large GIS data bases established by many mapping agencies all over the world. The objective of this research was to develop a rule based system for updating a spatial database. Taken into consideration were rules, such as: (a) The radiometric and textural parameters; (b) The geometric parameters of the objects, such as area, perimeter, compactness, elongation, etc; and (c) The topological relationships between objects of the same type group and from different layers, as well. This paper presents the algorithms and rules which were implemented for updating the Israeli National GIS spatial database. Also, discussed are the experiments implemented over the Haifa region test site.

1. INTRODUCTION

Updating of spatial databases can be carried out by complete, new and updated mapping, which replaces the existing old information. Alternatively, one may gather spatial details which are not found in the existing database. Their addition to this same database may constitute the major part of the updating process. The advantage of the last approach is the small amount of objects which require treatment. In this approach, databases updating processes are composed by three stages: (a) Change Detection - Finding objects and regions of change; (b) Change Recognition and Identification - Determination of the character and type of change; (c) Revision - Introducing the identified changes to the spatial database, while preserving the topology and the structure of the database.

Most of the traditional change detection and identification methods are based on the radiometric information from satellite or airborne remotely sensed data [Mouat, et al, 1993; Peled, 1993; Muchoney & Haack, 1994; Jha & Unni, 1994]. These methods are based on a comparison between the grey level values on two images from different dates. The common method of digital image comparison is image differencing. In this method, grey level values on two images are subtracted for each pixel. If the absolute value of the subtraction is greater than a specified threshold then the pixel is defined as a "changed" pixel, otherwise it is marked as "no changed" pixel. The major problem of these methods is the accuracy level of separating regions of change/no-change and identifying the type of change. In most studies, the thresholds are set empirically. To improve these methods, the analysts are looking for more automation. On the other hand, the automation processes, suffer from complex and uncertainty of the objects recognition. In the last years, most of the studies of change identification use the post-classification approach. In this approach two images of different epochs are classified and then, a pixel by pixel comparison is implemented. An example of these studies is the work of Muchoney & Haack [1994]. The major effort of these studies was to improve the classification method. Other research studies developed fuzzy logic algorithms to improve the classification methods [Bellacicco, 1996; Warner & Shank, 1997, Metternicht, 1999]. The problem of these works is the fact that they were based on single pixels classification, without taking into consideration entire objects. In recent years more and more identification methods were developed by using segmentation techniques to extract separate objects from the images [Tilton, J.C., 1998]. In this study [Tilton, 1998], the image is segmented using only radiometric criteria by using the Euclidean similarity distance. In general, most of the studies are focused only on a specific issue, such as improving the classification method, identifying thresholds or detecting changes for forest monitoring, rather than updating GIS databases.

The purpose of this ‘rule-based’ research study was the development of models and methods for updating the Geographical Information System (GIS), combining information from different sources, efficiently and automatically, as possible. The research focused, mainly, in the Change Identification stage. To achieve this objective, a rule based system was developed and examined. This system was built to integrate and fuse data from various sources. Taken into consideration were rules, such as: (a) The radiometric and textural parameters; (b) The geometric parameters of the objects, such as area, perimeter, compactness, elongation, etc; and (c) The topological relationships between objects of the same type group (class) and from different layers, as well.

2. METHODOLOGY

In this research, updating the spatial database is carried out based on the “detecting and identifying changes” approach. According to this approach the process of change detection was implemented in four major steps: (a) detecting regions which were changed; (b) calibration parameters and thresholds of the rule-based system; (c) segmentation of the regions of change to separated objects; and (d) identifying the type (class) for each changed object using the rule-based system.

A rule base system was developed for change identification. This system is based on four different types of parameters: (a) Spectral parameters; (b) Geometric parameters, such as area, perimeter, compactness, moments of inertia, etc.; (c) Textural parameters, such as contrast and homogeneity; and (d) Topological and spatial relations between the objects. According to these parameters, a set of rules was defined for each type (code) of objects. The rules were developed to describe each type (code), uniquely. For instance, a building is described by: specific spectral parameters, small area, compact shape, access way, etc. On the other hand, a street is described by: specific spectral parameters, elongated shape, connected to other streets, moderate slope, etc.

The algorithm for change identification was developed as a hierarchical decision tree, to integrate the different rules. The algorithm is implemented in two steps. The first step is to mark objects and clusters of pixels which were "changed". The detection was implemented in "object-wise" manner rather than single pixel treatment, as used in traditional methods. The labeling process is done by using the region growing segmentation method, which takes into consideration four different data sources: change intensity index, edge gradient, radiometric data and the objects from the existing spatial database. The second step is to identify the type of "change" using the set of rules.

3. DATA SOURCES

In this research, three data sources were used: National GIS spatial data layers, including the hypsographic data; Orthophoto generated from color photographs, for two different epochs; Multi-spectral IKONOS imagery. All of these data were fused and integrated into one spatial database, which was developed for the research experiments. The types of objects to be treated and tested were determined during the integration process. In addition, a quality control process [Peled, Gilichinski, 2004] was implemented to test the GIS spatial database. The results of the quality control process indicated serious problems especially in the values of the TYPE-CODE attribute for general objects and of the WIDTH attribute for road links. The detection of errors, their correction and removal, were essential to the system learning process and the specific spectral determination for each type-code processing.

4. EXPERIMENTS

4.1 Change Detection

The change detection process was implemented by comparing color orthophotos from different epochs. Different factors of detecting the "regions of changes" were tested. These factors are: (a) Change detection method category, whether it is a pre-classification or post-classification method; (b) Comparison implementation method for single pixels or for a small window around the single pixel; (c) Comparison between the RGB components or between other color components, such as HLS, HSI, L*a*b*, etc.; (d) Radiometric normalization; (e) Noise removal; (f) Methods for defining the "regions of changes" and the determination of thresholds for defining "significant" changes. The experiments included many combinations of these factors. Figure 1, illustrates some of the results of these experiments. According to these procedures two conclusions were made. The first was to use the Euclidean spectral distance in the L*a*b* color space to define the change magnitude. The second conclusion was that the optimal threshold to define a significant change is close to the value of one standard deviation of the change magnitude for all pixels in the research area.

4.2 Rule-Based System

The rule-based system which was developed includes sets of rules which supply a unique description for each type of objects. These sets of rules integrate radiometric, geometric, textural and topological parameters. The radiometric parameters include the distribution and other statistical parameters of the grey level values of each band for the pixels within each object (see figure 2). These parameters were computed only for objects within "no-change" regions. The geometric parameters include descriptors which define the geometrical characteristics of the object, such as area, perimeter, elongation, compactness, moments of inertia, etc. The textural parameters describe the textural template of grey level values for each band, such as: contrast and homogeneity. The topological parameters include topological and spatial relations between the objects from different types. These relations take into consideration instances such as if the object is within urban, rural, industrial, flat or mountainous zones.

4.3 Segmentation

In the segmentation algorithm distinguished are two groups of changed objects: (1) Objects, in the spatial database, that were changed totally; and (2) Clusters of pixels that were changed and are only part of objects within the ‘old’ database.

4.3.1 Whole Objects

Two methods were implemented to detect whole objects which were changed. In the first method, a change index was defined for each object in the existing spatial database. This index is calculated by averaging the change magnitude for each pixel within the object. If the value of this index exceeds specified criteria then the related object will be tagged as a changed object. Figure 3 shows some examples of objects which were tagged as “totally changed”. In the second method, a quality control process is performed. The quality control process detects objects which have irregular radiometric parameters. While building the rule-based system, for each type of objects were calculated the average and the standard deviation values of the histograms of grey level values in each radiometric band. For each grey level a range of normal population were determined by the average $\pm 2\sigma$ (σ = standard deviation). The quality control process counts, for each object, the number of grey level ranges which have population (percent of pixels) outside this range of “normal population”. If the counting results exceeded a specified threshold then the treated object was marked as "incorrect" type or "changed" object.

4.3.2 Clusters of Single Pixels

After the process of detecting whole objects which where changed, single pixels were tagged if the average of the change magnitude of the neighborhood pixels exceeded a specified threshold. The neighborhood pixels are defined by an operator of 9X9 pixels in size. This process is implemented for each pixel which falls within a specified region or any large area objects. The objective of defining this type of pixels is to detect whether a small part of large-area-objects was changed without affecting the change index (defined for the whole object). The segmentation process is implemented for the segmentation of clusters of these single pixels and their partitioning into separate objects. The newly developed segmentation algorithm is based on the region growing method. Seed pixels are selected according to the maximum change magnitude value. The growing criteria are taking into consideration the radiometric parameters and the gradient magnitude of the neighboring pixels. The gradient magnitude is computed using two directional 3x3 Sobel operators. Figure 4 shows an example of changed-pixels cluster which was detected as part of large-area-object.

4.4 Change Identification

After the process of labeling objects which were changed, a process of identifying the type of the change is implemented. The change identification process is performed using the rule-based system. This process consists of two tests for each object. The first test takes into consideration the radiometric and the textural parameters. For each type (code), the radiometric and textural parameters are checked whether they meet the specified rules. The result of this test could be zero, one or multi matching types. If no matching type is found then the object could not be identified. This could occur due to small area objects or untested types, such as building shadows or lack of statistically valid samples in the tested spatial database. On the other hand, if one matching type was found then the object will be identified by this step. Otherwise, the next test is implemented. This test includes the geometrical parameters and the topological relationships. This test is performed in a hierarchical order to find the best fitting type for the object. For example, the two buildings in figure (3b) were identified as "red" roof building (code=702) using only the radiometric and textural test. On the other hand, the road in figure (3d) was identified, in the first test, as dirt road (code=111) and also as "cultivated area" (code=608). However, by using the geometrical and the topological rules, in the second test, the system was able to define this object as a dirt road, due to the high value of the elongation and the connection to the road network.

5. SUMMARY

In each stage of this study, different methods were implemented and tested. Also, optimal thresholds were searched for, in order to enable automatic execution of these methods. In summary, the research has a number of contributions:

1. Automatic detecting and labeling of "changed" objects. The detection was implemented in "object-wise" manner rather than single pixel treatment, as used in many traditional methods. The labeling process is done by using the region growing segmentation method, which takes into consideration four different data sources: change intensity index, edge gradient, radiometric data and the objects from the existing spatial database.

2. Improvement of methods of classification, by using rule based system, both in terms of accuracy and efficient operation. The rule base system is based on four data sources: radiometric data, geometric parameters, texture parameters and topological relationships between different objects.

3. Implementing quality control process of the spatial database, according to the remotely sensed data. This process in itself is an important enhancement toward automatic updating of the spatial databases.

6. REFERENCES

Bellacicco, A., 1996. Fuzzy Logic in the Analysis of Spatial Data. In: *Sistema Terra: Remote Sensing and the Earth,* December, 1996, Rome, pp. 82-83.

Jha, C.S. & Unni, N.V.M., 1994. Digital Change Detection of Forest Conversion of a Dry Tropical Indian Forest Region. In: *International Journal of Remote Sensing,* 1994, Vol. 15, No. 13, pp. 2543-2552.

Metternicht, G., 1999. Change Detection Assessment Using Fuzzy Sets and Remotely Sensed Data: An application of topographic map revision. In: *ISPRS Journal of Photogrammetry and Remote Sensing,* Vol. 54, No. 4, pp. 221-233.

Mouat, D.A., Mahin, G.G. & Lancaster, J., 1993. Remote Sensing Techniques in the Analysis of Change Detetction. In: *Geocarto International (2)* 1993. pp. 39-50.

Muchoney, D.M. & Haack, B.N., 1994. Change Detection for Monitoring Forest Defoliation. In: *Photogrammetric Engineering & Remote Sensing*, October 1994, ASPRS, Vol. 60, No. 10, pp. 1243-1251.

Peled, A., 1993, Change Detection: First Step toward Automatic Updating, ACSM-ASPRS Annual Convention & Exposition Technical Papers, Vol. 3, pp. 281- 286, USA

Peled, A., Gilichinski, M., 2004. GIS-Driven Analyses of Remotely Sensed Data for Quality Assessment of Existing Land Cover Classification, 20th ISPRS Congress, 12-23 July, The International Archives of Photogrammetry and Remote Sensing, Vol. IV, Istanbul.

Tilton, J.C., 1998. Image Segmentation by Region Growing and Spectral Clustering with a Natural Convergence Criterion. In: *Proceedings of the 1998 International Geoscience and Remote Sensing Symposium*, Seattle, WA, July 6-10, 1998.

Warner, T.A., & Shank, M., 1997. An Evaluation of the Potential for Fuzzy Classification of Multispectral Data Using Artificial Neural Networks. In: *Photogrammetric Engineering & Remote Sensing,* November 1997, Vol. 63, No. 11, pp. 1285-1294.

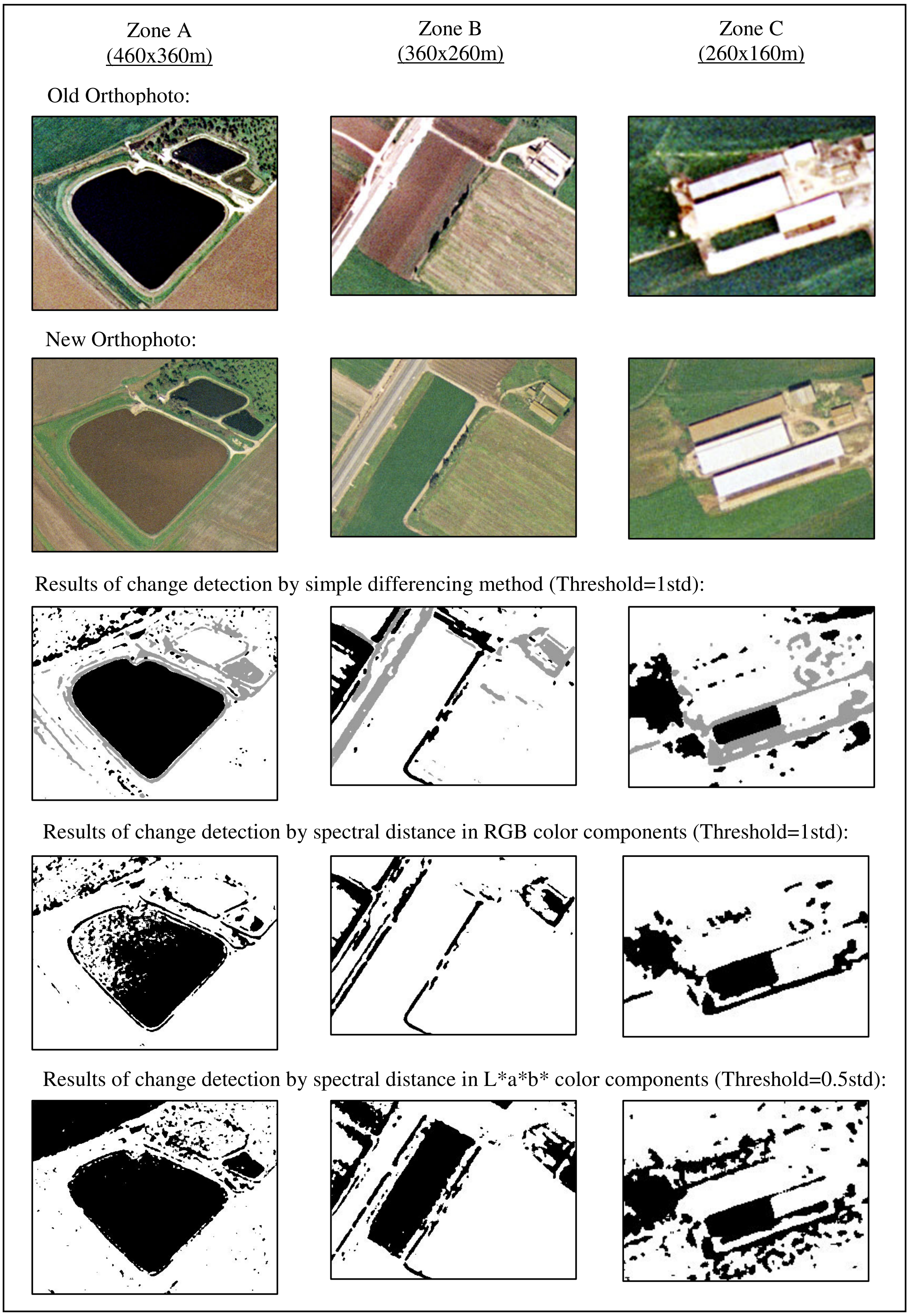
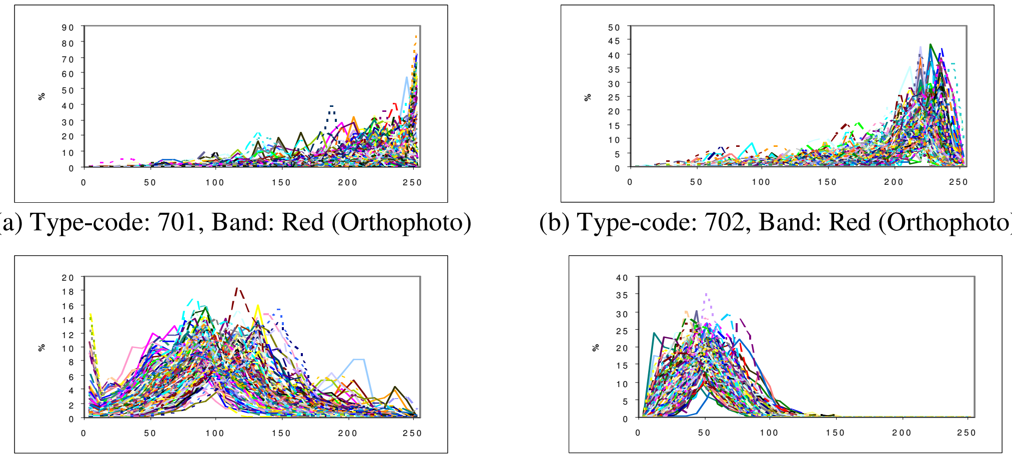


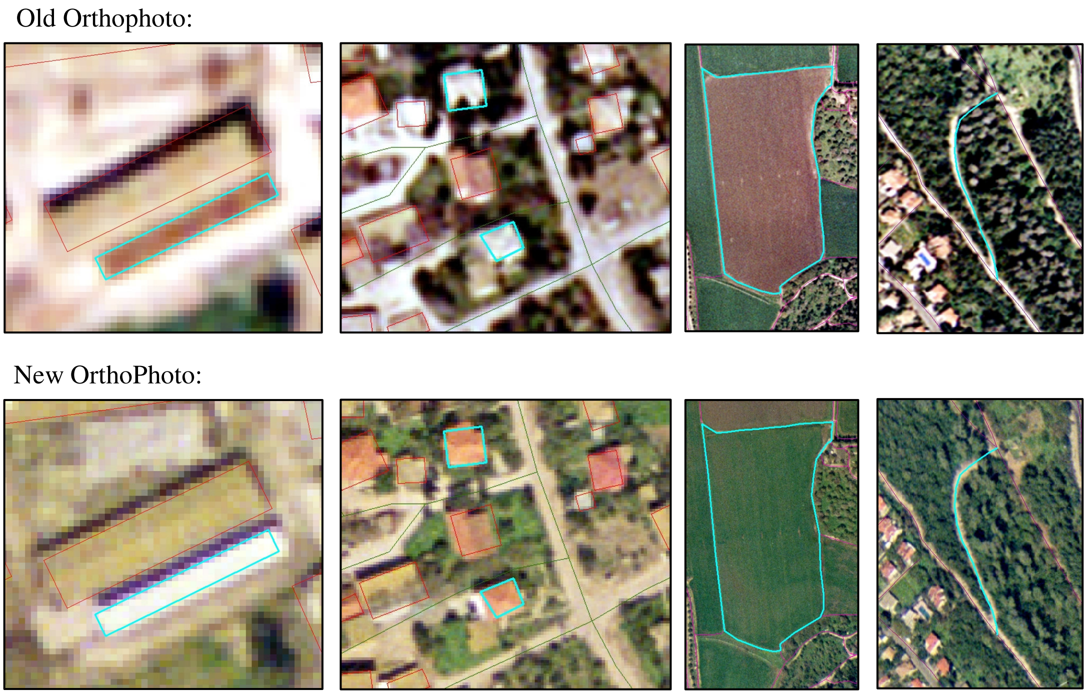
Figure 1: Examples of results of change detection experiences in three different zones and using three methods. Shown are the enhanced results by 5x5 majority filter.



(a) Type-code: 701, Band: Red (Orthophoto) (b) Type-code: 702, Band: Red (Orthophoto)

(c) Type-code: 624, Band: Red (Orthophoto) (d) Type-code: 624, Band: NIR (IKONOS)

Figure 2: Examples of grey level distributions on pixels within unchanged objects sorted by object types and spectral bands.



(a) (b) (c) (d)

Figure 3: Examples of whole objects (outlined with cyan line) which define as changed.

(a) Old Orthophoto (b) New Orthophoto (c) Changed pixels

Figure 4: Example of changed pixel cluster which was detected as a part of large area object.